LUNAR AND PLANETARY MISSIONS
LAUNCHED FROM A GEOSYNCHRONOUS TRANSFER ORBIT*

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ABSTRACT

Considerable cost and mass savings are possible by launching small spacecraft into lunar and planetary space as secondary payloads. The Ariane, for example, provides a platform for several such payloads on each of its monthly launches of placing communication satellites into geosynchronous orbits. Specifically, the second stage injects into a geosynchronous transfer orbit (GTO), and can accommodate six spacecraft, each weighing about 80 kg. This paper addresses the question of how and for what propellant cost can a spacecraft be launched from GTO to the Moon or other deep space bodies.

We begin with the constraints imposed by the GTO itself. Briefly, launch takes place in the early hours of the morning so that GTO apogee occurs at noon local time. The inclination with the equator is about 7 deg (for Ariane), with perigee and apogee altitudes of 620 km and 35,880 km, respectively. After primary payload separation, the GTO stage remains parked in this highly elliptic orbit indefinitely. The small payloads may be separated from the stage at any time, and use its own propulsion system to inject to the Moon or another body. The focus of this paper is to determine which targets are available from this predetermined parking orbit, what wait-time in orbit is required, which flight options should be used, and what the propulsion costs are.

An example analyzed briefly for Mars is given in Table 1. Additional details of the analysis will be presented in the paper. Fortunately, in the case of Mars, a noon-time apogee placement of the GTO is favorable for using a direct injection to Mars with certain constraints. The required wait time in orbit before injection to Mars is approximately 2 months. After this orbit stay time, applying a boost of about 1.2 km/sec at perigee will inject the spacecraft in the direction necessary to go to Mars. Also, since the GTO parking orbit is near equatorial, the escape asymptote must have a declination close to zero which, in turn, restricts launch and arrival dates to certain time periods. The dates given in Table 1 lie within these time intervals. This analysis takes into account nodal regression and other perturbations on the GTO orbital elements.

An alternate method, which reduces propellant requirements but increases flight time, is to use two lunar flybys together with an Earth powered gravity assist. In this case, 0.700 km/s would be needed at GTO perigee for injection to the Moon, and another 0.250 km/sec for the Earth powered flyby, reducing the overall propellant usage. A detailed analysis of this approach will be given in the paper.

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Table 1. Requirements for GTO Injected Payloads Direct to Mars

Opportunity	C3	Flt Time (mo)	DV (m/sec)	Propellant* (%)
Jan 1999 (Type 2)	8.5	11	**1180**	26
Mar 2001 (Type 2)	9.5	9	1220	27
Mar 2003 (Type 1)	9.5	7	1220	27
Aug 2005 (Type 2)	16	12	1500	32

*Specific impulse assumed is 390 sec.

In addition, the paper considers various options available in matching the constrained GTO ellipse to the necessary escape direction for the body considered. These are: (1) the use of multiple impulses, such as a plane change at apogee, (2) the use of single or multiple lunar flybys, (3) escape orbits which may return to Earth in 6 months or a year for additional Earth or lunar flybys, and (4) near escape orbits which allow solar perturbations to shape the orbit for an Earth powered flyby . These effects may be used singly, or in combination to enable specific missions to asteroids and comets, as well as Venus and Mars. The references below discuss some of these methods in detail.

REFERENCES

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